REMARKS

Examiner Baumeister is thanked for the courtesies extended to Applicant's representatives during the telephone interview conducted on August 26, 2004. Applicant's separate record of the substance of that interview is incorporated into the following discussion.

Claims 1, 3, 5-12 and 21 are currently pending. Claims 1, 10, 12 and 21 have been amended herein. Claims 2 and 16-18 have been canceled herein without prejudice. Claims 1, 10, 12 and 21 have been amended to include the limitations of claim 2 and to remove "a doped" from the phrase "a doped electron-supplying layer." Applicant respectfully submits that none of the amendments change the scope of the claims beyond that of the previously examined submissions.

Applicant's Response to the Objection to Drawings

The drawings stand objected to under 37 C.F.R. §1.83(a) for failing to identify every feature of the claimed invention. Specifically, the Office Action asserts that the drawings do not illustrate an electron supplying layer in contact with the first channel layer as opposed to possessing an interposed offset spacer. In response thereto, Applicant has amended claims 1, 10, 12 and 21 by removing the phrase "a doped" from the disclosure of "a doped electron-supplying layer." Applicant respectfully submits that the interposed offset spacer is in fact a non-doped spacer layer 5 in Figure 1. Hence, the disclosure of the electron-supplying layer in the claims encompasses both the doped layer 6 and undoped layer 5. Hence, the electron supply layer encompasses the broader meaning as set forth at page 5, paragraph 3 f.i. of the Office Action.

Applicant submits that this amendment to the claims clarifies Applicant's intent and that the limitations as set forth in the amended claims are fully illustrated in the drawings. Wherefore, removal of the objection is respectfully requested.

Applicant's Response to the Rejections under 35 U.S.C. §103(a)

Claims 1-3, 5, 6, 9, 17 and 18 stand rejected under 35 U.S.C. §103(a) as being unpatentable over ***JP 6-236898*** and Applicant's admitted prior art in view of ***JP '934***. In response thereto, Applicant has amended the claims to more distinctly describe the subject matter regarded as the invention. Specifically, Applicant has incorporated claim 2 into claim 1. Additionally, Applicant respectfully traverses on the basis that the present invention would not have been obvious because ***JP '898*** teaches away from the present invention and that all the limitations are not present in the cited references.

The present invention, as set forth in the claims, relates to an HEMT having the structure of InP substrate/InGaAs channel layer/InAlAs electron-supplying layer. According to this type of HEMT, an InGaAs channel layer has high electron mobility so that high-speed response can be achieved. However, since the InGaAs channel layer has a small energy band gap, the impact ionization ratio in the channel layer is increased in a high electric field. The impact ionization generates electron-hole pairs in the channel layer, resulting in excess drain current and degraded drain resistance.

In order to avoid such impact ionization, the present invention has the second channel layer of In(AlGa)As or Group III-V compound semiconductor using Group V element other than P, that has the wider energy band gap than InGaAs first channel layer,

between the InGaAs first channel layer and the buffer layer on InP substrate. Further, per the addition of the limitations of claim 2 into the independent claims the first and second channel layers are formed to have thickness small enough to have discrete quantum levels, a first quantum level being formed only in the first channel layer, and a second quantum level being formed in both the first and second channel layers. According to this structure, electrons exist at the first quantum level in the first channel layer under a lower electric field, and a large amount of electrons exist at the second quantum level under a higher electric field, so that a larger amount of electrons can exist and move in the second channel layer. Since the second channel layer has a wider energy band gap than the first channel layer, it can suppress the impact ionization more, compared to the first channel layer. Therefore, excessive drain current is avoided.

The current Office Action states that since the description in the prior art of the present application explains that ***JP '898*** shows that InGaAs first channel layer and InGaAsP second channel layer having wider energy band gap, it is obvious for a skilled person to employ an In(AlGa)As stress compensation layer 3 instead for the InGaAaP second channel layer. Further, the Office Action maintains that ***JP '898*** discloses "the first and second channel layers are formed to have the thickness small enough to have discrete quantum levels, a first quantum level being formed only in the first channel layer, and a second quantum level being formed in both the first and second channel layers" of original claim 2.

According to ***JP '898***, especially Fig. 2, there are two channel layers, InGaAsP layer 3a having Eg = 1.1eV at the substrate side and InGaAsP layer 3b having Eg = 0.9eV at the surface side. There is no disclosure of the first channel layer of InGaAs.

The inventor has examined whether or not the example of ***JP '898*** has the thickness according to which a first quantum level is formed only in the first channel layer, and a second quantum level is formed in both the first and second channel layers. As demonstrated in the attached § 132 Declaration, the InGaAsP first channel layer 3b has a large thickness so that the first and second, or other quantum levels are formed in the first channel layer and more higher quantum levels are formed in both the first and second channel layers. Therefore, according to ***JP '898***, electrons exist at the first and second, or additional quantum levels in the first channel layer under a high electric field. Hence, the impact ionization is not avoided due to the first channel layer's small energy band gap width.

On the other hand, in the present invention, the InGaAs first channel layer has a small thickness so that the first quantum level is formed only in the first channel layer, and the second quantum level is formed in both the first and second channel layer. The thinner the channel layer is, the higher the second or higher quantum levels are. In ***JP '898***, since the first channel layer has a thickness of 25nm or at least 12nm (*see* paragraph [0028], [0036]), comparing to the present invention thickness of 3-7nm (*see* page 9, line 19), not only the first quantum level but also the second quantum level are formed in the first channel layer. This is evidenced by the inventor's findings as set forth in the attached §132 Declaration.

According to the present invention, since the second quantum level is formed in both the first and second channel layers, a large amount of electrons exist at the second quantum level under a higher electric field and many electrons can exist in the second channel layer. Therefore, the impact ionization of electrons is avoided in the second

channel layer. If the first and second quantum levels are formed only in the first channel layer, all electrons at the first and second quantum levels exist only in the first channel layer. Further, in the present invention, the second channel layer is thicker than the first channel layer. Therefore, when the electrons exist at the second quantum level, more electrons exist in the second channel layer than in the first channel layer. Furthermore, more electrons can exist in the second quantum level than in the first quantum level. Wherefore, Applicants respectfully submit that the cited art does not disclose all the limitations of the presently claimed invention.

Applicants further submit that ***JP*** '898 in fact teaches away from a combination which results in the present invention. According to paragraph [0012] of ***JP '898***, InGaAsP which is capable of limiting impact ionization, is employed as the channel layer rather than InGaAs which is disclosed as not capable of limiting the impact ionization. The paragraph further discusses that if the InGaAsP channel layer is employed, the conduction band level difference delta Ec between the InGaAsP channel layer and the InAlAs electron-supplying layer becomes smaller, and therefore, enough electrons cannot be confined in the channel layer. Therefore, in ***JP '898***, the InGaAsP first channel layer has a larger thickness, *e.g.*, 25nm in the second embodiment (paragraph [0028]), and 12nm in the fourth embodiment (paragraph [0036]), so that enough electrons can be confined in the channel layer regardless of the small conduction band level difference. As the result, ***JP '898*** teaches toward the first channel layer having a larger thickness and plurality. In this embodiment, the lower order quantum levels are formed only in the first channel layer in ***JP '898***.

On the other hand, the present invention employs an InGaAs first channel layer in which the impact ionization cannot be suppressed. Therefore, ***JP '898*** teaches away from this point of the present invention. In the present invention, since, the InGaAs first channel layer is employed, the conduction band level difference delta Ec between the InAlAs electron-supplying layer and the first channel layer is large enough to confine electrons in the first channel layer, regardless of its thinness. According to the thinness of the first channel layer, the first quantum level can be formed only in the first channel layer and the second quantum level can be formed both in the first and second channel layers, per original claim 2 as now incorporated.

In regard to ***JP '934***, the reference likewise does not teach an embodiment which is combinable to result in the present invention. The In(AlGa)As layer 3 is not a channel layer but the stress compensation layer. And, since the conduction band level of In(AlGa)As layer 3 is too high, it is difficult for electrons to exist in the layer 3, therefore, such layer 3 cannot be a channel. Therefore, the electrons cannot move in this stress compensation layer 3, because it is not the channel layer 4. Further, the InGaAs channel layer 4 has a large thickness 200Å so that plural quantum levels are formed only in the channel layer 4.

Therefore, although the stress compensation layer 3, not the channel layer, is In(AlGa)As in ***JP '934***, it is not obvious for the persons skilled in the art to employ the In(AlGa)As layer of ***JP '934*** substituting for the InGaAsP second channel layer of ***JP '898*** because there is no incentive for the skilled person to employ a non-channel layer, In(AlGa)As, as the second channel layer of ***JP '898***. Therefore, one skilled in the art in light of the disclosed references would not have derived the present invention.

Fig. 6 shows the InGaAs first channel layer 104 and InGaAsP second channel layer 103. However, ***JP '898*** shows InGaAsP first channel layer and InGaAsP second channel layer (ratio of P is different from each other). ***JP '898*** does not disclose the structure of Fig. 6 in the present specification.

For at least the foregoing reasons, it is believed that this application is now in condition for allowance. If, for any reason, it is believed that this application is not in condition for allowance, Examiner is encouraged to contact the Applicants' undersigned attorney at the telephone number below to expedite the disposition of this case.

In the event that this paper is not timely filed, Applicants respectfully petition for an appropriate extension of time. Please charge any fees for such an extension of time and any other fees which may be due with respect to this paper, to Deposit Account No. 50-2866.

Respectfully submitted,

WESTERMAN, HATTORI, DANIELS & ADRIAN, LLP

By:

Stephen G. Adrian
Reg. No.: 32,878
Attorney for Applicant
Tel: (202) 822-1100
Fax: (202) 822-1111

Attachments: §1.132 Declaration
Petition for Extension of Time w/fee
Request for Continued Examination w/fee

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